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SYNTHETIC APERTURE OPTICAL SYSTEM

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Synthetic Aperture Optical System

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Abstract

The resolution of a traditional optical system is proportional to its light path diameter. Merely increasing the diameter of the light path will lead to increase in cost and make it difficult for manufacturing, testing and assembling the optical system. Further more, the ability to increase the light path diameter is subject to the limit in manufacturing capability. Therefore, there is a limit in increasing resolution by manipulating aperture. Synthetic aperture optical system is an effective way in getting around this problem. Here, we will discuss about some of the fundamental principles in synthetic aperture technology and provide some of application cases.

Key Words: synthetic aperture, optical system, principle, application.

1. Basic Concepts

Synthetic aperture system is also called phased array optical system. It is formed by combining a group of independent telescopes or imaging system through interference as it is shown in fig.1.

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* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

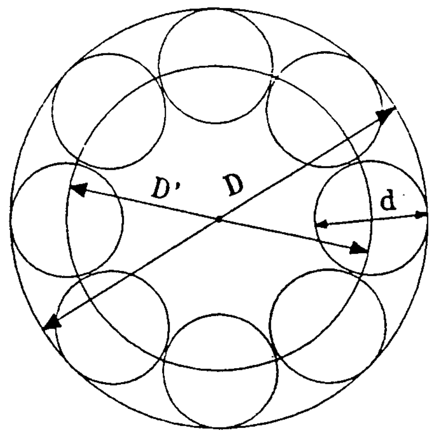

Fig.1 Synthetic aperture concept diagram

One of the most important use of synthetic aperture is in imaging system. The synthetic aperture used in interference imaging has two basic structure(2,3) as it is shown in fig.2. The first kind is SMT(segmented mirror telescope) which consists of a divided mirror and a shared mirror as it is shown in fig. 2(a). The second kind is PAT(phased array telescope) which consists of multiple independent telescopes and a phased array optical system formed by interference imaging combination system(fig.2(b).

The imaging in SMT is a one step process, we will not discuss it here. The imaging in PAT is two step process as it is shown in fig.2(b). The first step is an aperture transformation during which incoming aperture is transferred to the incoming aperture plane of light combination system B; It is then gone through Fourier transformation in this light combination system, during which interference image is determined by aperture function. In order to obtain high resolution interference image on the focal plane of light combination system, an aperture transformation has to be done so that the aperture of the whole system can be accurately amplified. Therefore, aperture transformation has to enable every aperture satisfies

One of the most important application of the synthetic aperture is in imaging system $M_c/M_t=1$ (for every n)

$$M_t = D'_n/D_n$$

$$M_c = r'_n/r_n$$

$$M_c/M_t = 1$$

M_t is the magnification of telescope, M_e is the magnification of the aperture transformation system.

2. Principle Analysis

As we know, the aperture function of a circular single aperture system can be described as

(1)
$$P_0(x,y) = \mathrm{circ}(\sqrt{x^2+y^2}/r) \cdot \exp\{-i2\pi\omega(x,y)\}$$

A synthetic aperture system which has identical aperture, the aperture function can also be described mathematically,

(2)
$$P(x,y) = \mathrm{circ}(\sqrt{x^2+y^2}/r) \cdot \exp\{-i2\pi\omega(x,y)\} * \sum_{n=1}^{N}\delta(x-x_n, y-y_n)$$

According to Fourier optical theory, the profile of a synthetic amplitude is the Fourier transformation of an aperture function P(x,y),

(3)
$$\begin{aligned} O(x,y) &= \mathscr{F}\{P(x,y)\} \\ &= \mathscr{F}\{\mathrm{circ}(\sqrt{x^2+y^2}/r) \cdot \exp[-i2\pi\omega(x,y)] * \sum_{n=1}^{N}\delta(x-x_n, y-y_n)\} \end{aligned}$$

When wave difference ceases to exist, i.e, when w(x,y)=0, according to Fourier transformation property, (3) can be converted to

$$\begin{aligned} O(x,y) &= \mathscr{F}\{\mathrm{circ}(\sqrt{x^2+y^2}/r)\} \cdot \mathscr{F}\left\{\sum_{n=1}^{N}\delta(x-x_n, y-y_n)\right\} \\ &= \frac{\pi r^2}{2\lambda f}\left(\frac{2J_1(2\pi r(\sqrt{x^2+y^2}/\lambda f)}{2\pi r\sqrt{x^2+y^2}/\lambda f}\right) \cdot \sum_{n=1}^{N}\mathscr{F}\{\delta(x-x_n, y-y_n)\} \\ &= \frac{\pi r^2}{2\lambda f}\left(\frac{2J_1(2\pi r\sqrt{x^2+y^2}/\lambda f}{2\pi r\sqrt{x^2+y^2}/\lambda f}\right) \cdot \sum_{n=1}^{N}\exp[-i2\pi(xx_n+yy_n)/\lambda f] \end{aligned}$$

If we square the above expression, we can obtain the diffraction intensity profile for the imaging system,

(4)
$$I(x,y) = \frac{\pi^2 r^4}{4\lambda^2 f^2}\left(\frac{2J_1(2\pi r\sqrt{x^2+y^2}/\lambda f)}{2\pi r\sqrt{x^2+y^2}/\lambda f}\right)^2 \cdot \left|\sum_{n=1}^{N}\exp[-i2\pi(xx_n+yy_n)/\lambda f]\right|^2$$

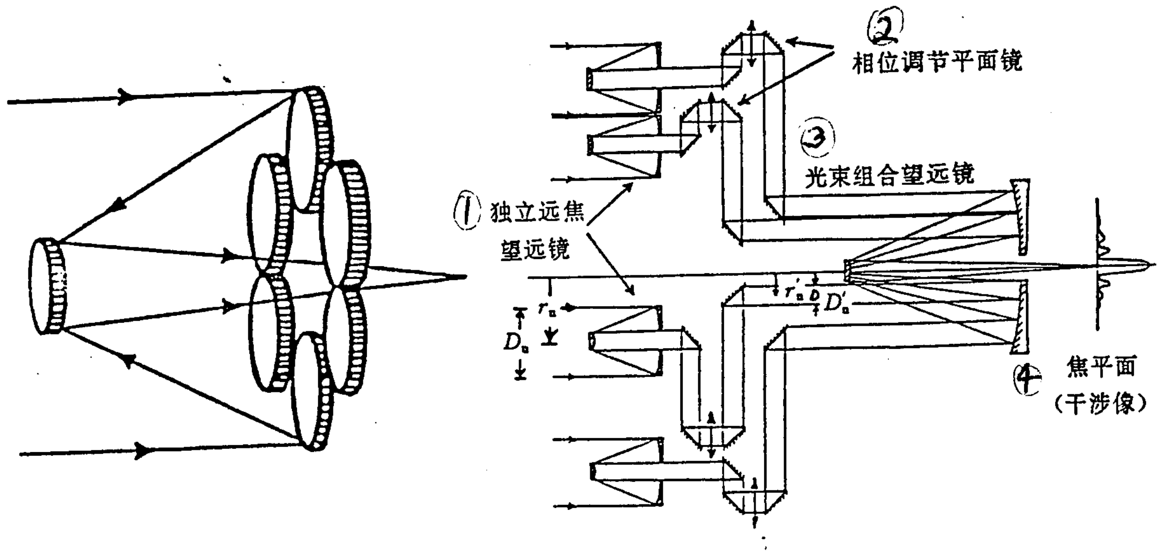

Fig.2 The interference image in synthetic aperture system

Key:
(1) independent long focal length telescope;
(2) phased adjustment mirror;
(3) light beam combining telescope;
(4) focal plane(interference image).

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is wavelength of incoming wave; f--system focal length; J_1--the stage Bisar function.

As we see from above, the energy distribution in far field of synthetic aperture system is the interference synthesis of each phased array, interference fringes are a function that embodies the diffraction of each aperture. In another word, synthetic aperture enables energy redistribution in every single aperture. This results in "0" interference and narrower band which translates into higher resolution. Based on this, an optical system that closes or exceeds diffraction limit can be designed.

3. The advantage and the application of synthetic aperture system

Synthetic aperture optical system has many advantages. First of all, multiple telescopes produced by ordinary chemical methods at very low cost can give rise to high resolution by interference combination. High aperture, high resolution imaging system obtained through using ordinary optical system helps getting around the problem in manufacturing and testing larger optical parts.

Synthetic aperture optical system is more compact than single aperture system that has identical F values. Its strong structure makes it very useful for infrared guided, highly mobile missiles in space.

In addition, the compact synthetic aperture structure ensures fast and even cooling of the whole optical system.

At present, the synthetic aperture technology has been widely used in astronomy. The space telescopes of NASA and COSMIC have used this technology, and their resolution has reached 0.01 urad; US National New Technology telescope(NNTT) has 0.0023 mrad resolution after using four 7.5m diameter telescope that is built with synthetic aperture technology. Nanjin Astronomy observatory proposed a plan to build optical and infrared telescope using synthetic aperture technology which will give rise to a resolution that is equivalent to a 10 meter diameter optical system.

Synthetic aperture technology also found its use in military areas such as early warning, monitor and guidance. The anti-satellite missile F15-MHV that is mounted on a fighter jet developed by US has a synthetic aperture system composed of 8 telescopes as it is shown in fig.3. In a test done in Sep of 1985, a missile which was fired from a F15 jet at 10,000 m elevation, successfully hit a satellite which is about to expire and blew it into pieces.

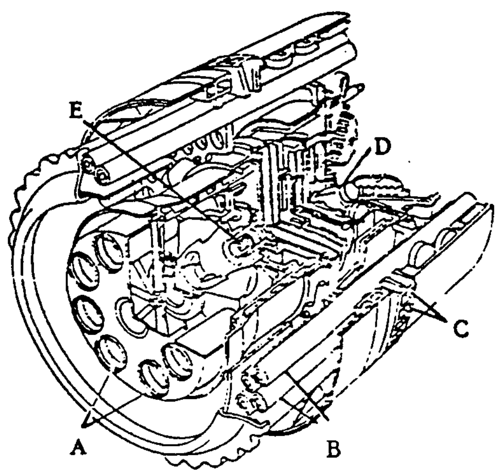

Fig.3 F15-MHV interceptor anatomy

A---Low temperature cooling infrared telescope
B---Thrust generator
C---Lateral engine opening
D---Laser torsional pendulum based sensor
E---Infrared detector

References

1. J.S. Fender, "Phased Array Optical Systems", Proc. SPIE 643(1986).

2. J.E. Harvey, ed., "A Parametric Study of Various Synthetic Aperture Telescope Configurations for Coherent Imaging Applications", Proc. SPIE 643(1986).

3. Yan Guo Guang, Wang Zi Yu, "Preliminary study on multiple array optical telescopes", special report, 1990.

4. Zhao Da Zun, "Optical Wave Science", National Defense Press, 1983.

5. B. Davis, ed., Coherent optical system of modular imaging collectors(COSMIC): "an approach for a large aperture high angular resolution telescope in space", Proc. SPIE 440(1984).

6. Yang Ying Huai et al., "synthetic aperture infrared imaging optical system", Infrared Light and Laser Technology, 1989, No.3.

7. Ma Ping Zhong, "discussion on designing synthetic aperture telescope", Optical and Electrical Engineering, 1991. No.4.

8. Sun Chen Jun, "the analysis and calculation on US made infrared guided anti-satellite interceptor F15-MHV", Communique on Advanced Defence Weapons, 1990, No.8.

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